# Basin-Scale Analysis, Management Tools, and Options for Produced Water from Tight-Gas Sand Reservoirs, Uinta Basin, Utah

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### Abstract

The production and disposal of water from tight-sand gas reservoirs in the eastern Uinta Basin, Utah, and elsewhere affects the economics of gas resource development and has recently become a topic of much public debate because produced water is the largest-volume waste stream associated with these unconventional gas plays. Managing produced water can be a significant cost fraction of the value of the gas extracted, so there is an economic incentive to minimize this waste stream, and/or generate revenue from treating and reusing produced water in hydrocarbon production or other applications. Balancing the water-use needs and produced-water disposal requirements associated with shale/tight-sand gas development creates significant material handling challenges to both industry and regulators. These challenges are complicated by an operating environment where many individual producers of varying sizes exist within a field, each with varying water needs and production, and a production timescale of decades for the basin as wells play out and new ones are completed.

Over 328 BCFG and nearly 50 million bbls of water were produced from the Uinta Basin in 2013. The major tight-gas sand reservoirs in the basin are the Tertiary (Eocene) Wasatch Formation and several formations in the Cretaceous Mesaverde Group. Potential uses for the produced water from these formations include water flooding for secondary recovery, drilling mud formulation, hydraulic fracturing fluid for well completion, and future oil shale production. In addition, some produced water has potential for geothermal energy production. Our study consists of four major components: (1) compilation and analysis of past and new information on the thickness, structure, depth, lithology, water quality, and temperature of all aquifer/ reservoir units in the basin from the surface (alluvial) down through the Jurassic Glen Canyon Group; (2) statistical analysis of water production quantity and quality to identify and forecast volume trends for each discrete tight-sand gas-producing interval; (3) development of alluvial aquifer sensitivity/vulnerability models to potential contamination from fluids associated with tight-sand gas development; and (4) an evaluation of the existing infrastructure for produced water management/reuse and recommendations for best management practices and the energy generation potential of geothermal-produced waters.

### Acknowledgments



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### Disclaimer

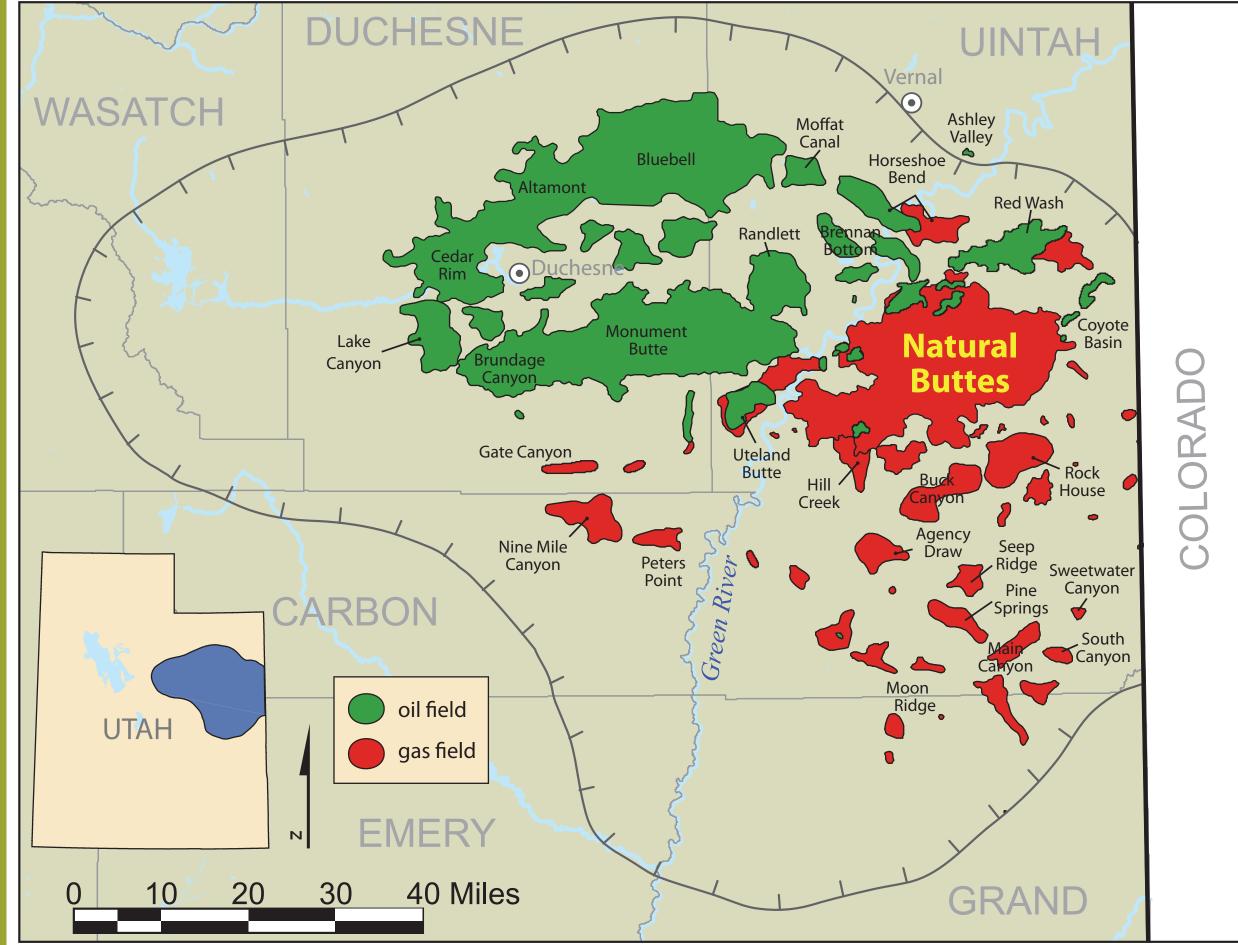
Although this product represents the work of professional scientists, the Utah Department of Natural Resources, Utah Geological Survey, makes no warranty, expressed or implied, regarding its suitability or a particular use. The Utah Department of Natural Resources, Utah Geological Survey, shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to claims by users of this product.

# Project and Regional Overview

# Study Objectives

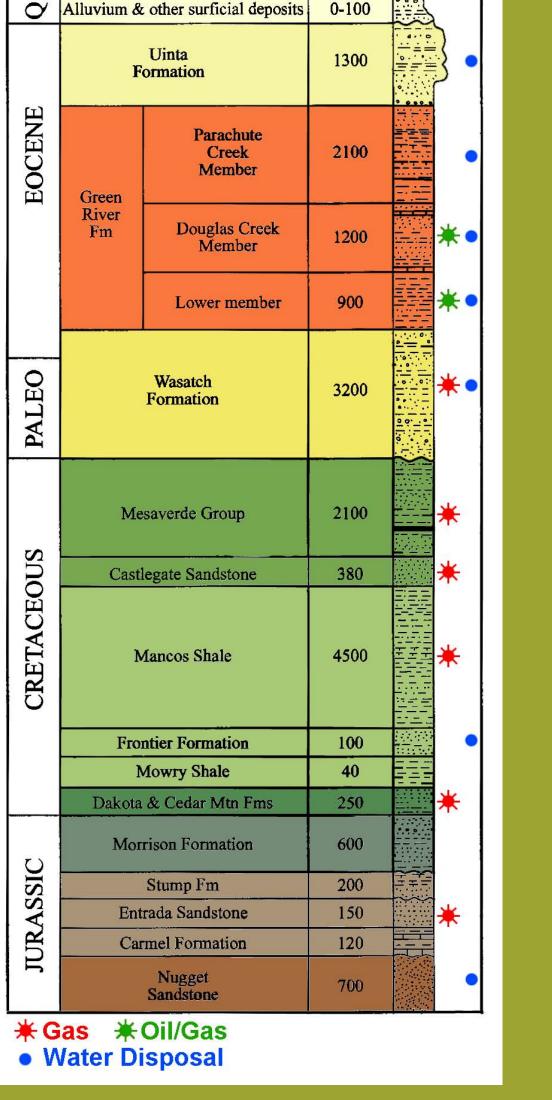
- Create basin-wide, digital produced water management tools.
- Integrate produced water character, water disposal/reuse, water transport, and groundwater sensitivity factors to allow for quicker and more efficient regulatory and management decisions related to unconventional gas developments.
- Investigate the option of beneficial use of produced water treatment for geothermal heat recovery or power
- Promote maximized produced water reuse, which will minimize use of freshwater in unconventional gas development and production.
- Compile Uinta Basin produced water management practices and identify best practices.
- Seek to increase protection of critical Uinta Basin alluvial aquifers

### Oil and Gas Fields of the Uinta Basin, Eastern Utah





### Eastern Uinta Basin



## Gas & Water Production, Uinta Basin

### Drilling Activity, Uinta Basin



### **Drilling Permits (APDs)**

**2010 - 1148** 

**2011 - 1490** 

**2012 - 2068 2013 - 1550** 

**2010 - 948** 

**2011 - 969** 

**2012 - 1087 2013 - 963** 

### Photos courtesy of Brad Hill, Utah Division of Oil, Gas, & Mining

### Gas Production Water Production

■ 2010 - 404 BCF ■ 2010 - 93 million bbls

■ 2011 - 432 BCF ■ 2011 - 100 million bbls

■ 2012 - 464 BCF ■ 2012 - 98 million bbls ■ 2013 - 324 BCF ■ 2013 – 87 million bbls

■ Cumulative - 4.1 TCF
■ Cumulative - 3.4 billion bbls

Source: Utah Division of Oil, Gas, & Mining, 2014. Note: 2013 production and cumulative numbers are through October 2013.

# Produced Water Management Practices

### PANEL

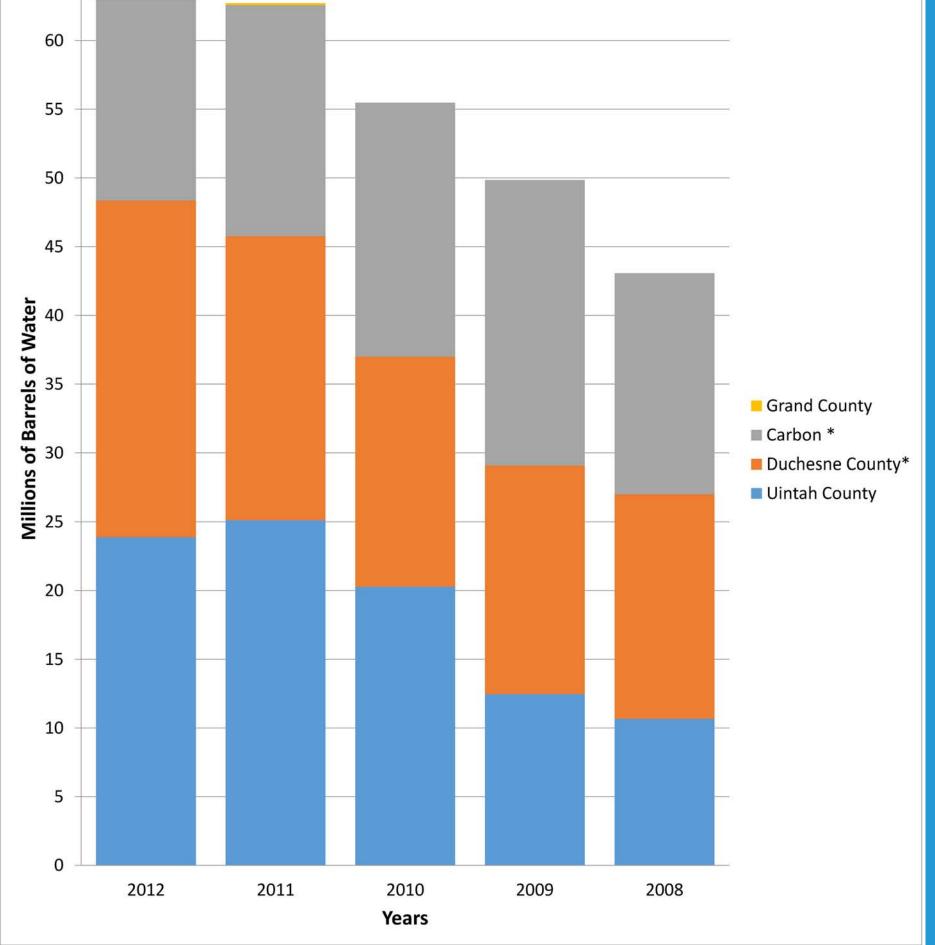
# Number of Water Disposal Wells

(source: Utah Division of Oil, Gas, & Mining) The number of water disposal wells jumped by over 25% from 59 in 2009 to 75 in 2010 and has remained in the mid-70s since then. There is typically one disposal well for every 130 to 160 producing wells In the Uinta Basin. Counties with an asterisk include coalbed-gas disposal wells.

### Enhanced-Oil Water Injection Volumes

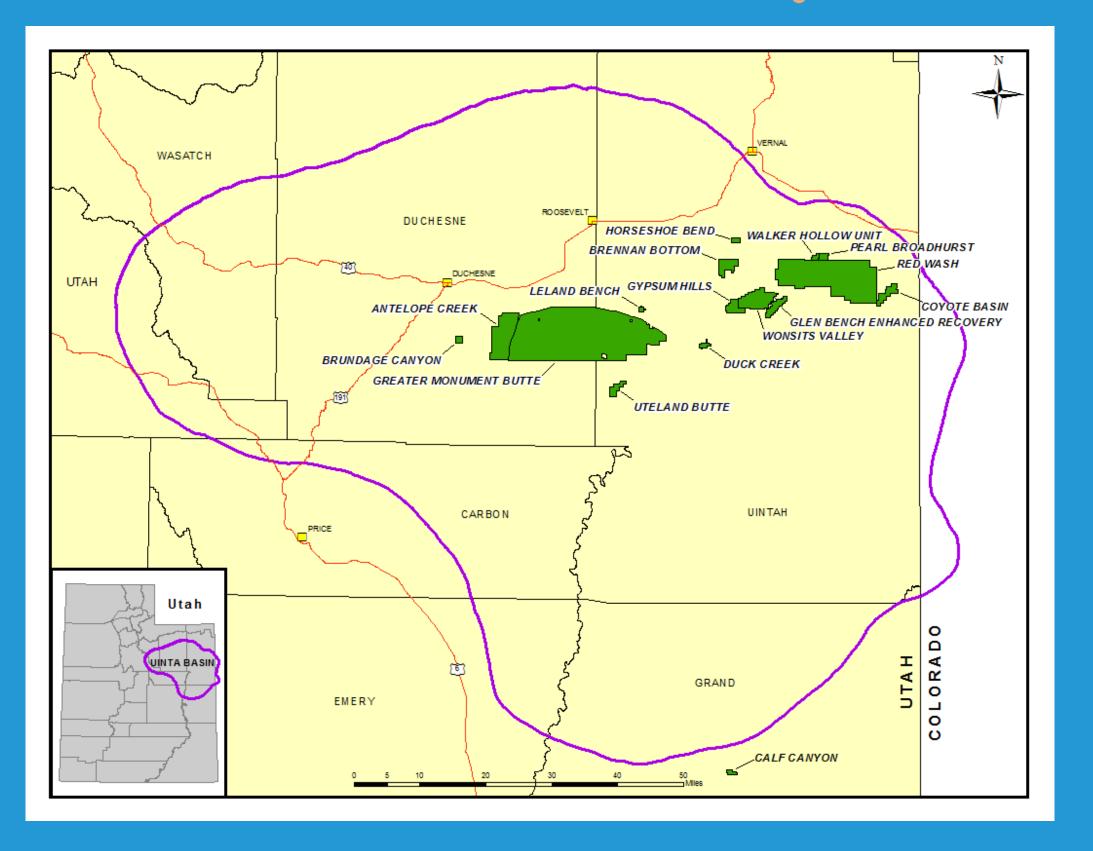
ENHANCED-OIL PROJECT NAME	COUNTY	<u>2012</u>	<u>2011</u>	<u>2010</u>	<u>2009</u>	<u>20</u>
Antelope Creek	Duchesne	1.25	1.20	1.48	1.71	1.
Brundage Canyon	Duchesne	0.74	0.36	0.17	0.02	0.
Uteland Butte	Duchesne	0.03	0.03	0.01	0.03	0.
<b>Greater Monument Butte Unit</b>	<b>Duchesne-Uintah</b>	22.26	16.55	15.12	11.08	10.
Calf Canyon	Grand	2.08	0.00	0.00	0.00	0.
<b>Brennan Bottom</b>	Uintah	0.04	0.07	0.06	0.08	0.
Coyote Basin	Uintah	0.00	0.00	0.00	0.00	0.
Duck Creek	Uintah	0.06	0.05	0.13	0.28	0.
Glen Bench Enhanced Recovery	Uintah	0.43	0.47	0.42	0.42	0.
Gypsum Hills	Uintah	0.36	0.25	0.38	0.25	0.
Horseshoe Bend	Uintah	0.02	0.00	0.01	0.00	0.
Leland Bench)	Uintah	0.11	0.07	0.03	0.03	0.
Pearl Broadhurst	Uintah	0.11	0.14	0.13	0.13	0.
Red Wash	Uintah	3.39	3.94	4.33	4.87	8.
Walker Hollow	Uintah	1.29	1.24	1.25	1.21	1.
Wonsits Valley	Uintah	1.37	1.96	2.07	2.72	2.
TOTAL		33.54	26.33	25.59	22.82	25.

Million Barrels Disposed



then leveled off in 2012 at about 63 million barrels. On average, each disposal well injects from 0.7 to 0.9 million bbls of produced water per year. Counties with an asterisk include coalbed-gas disposal wells.

### Location of Enhanced-Oil Projects



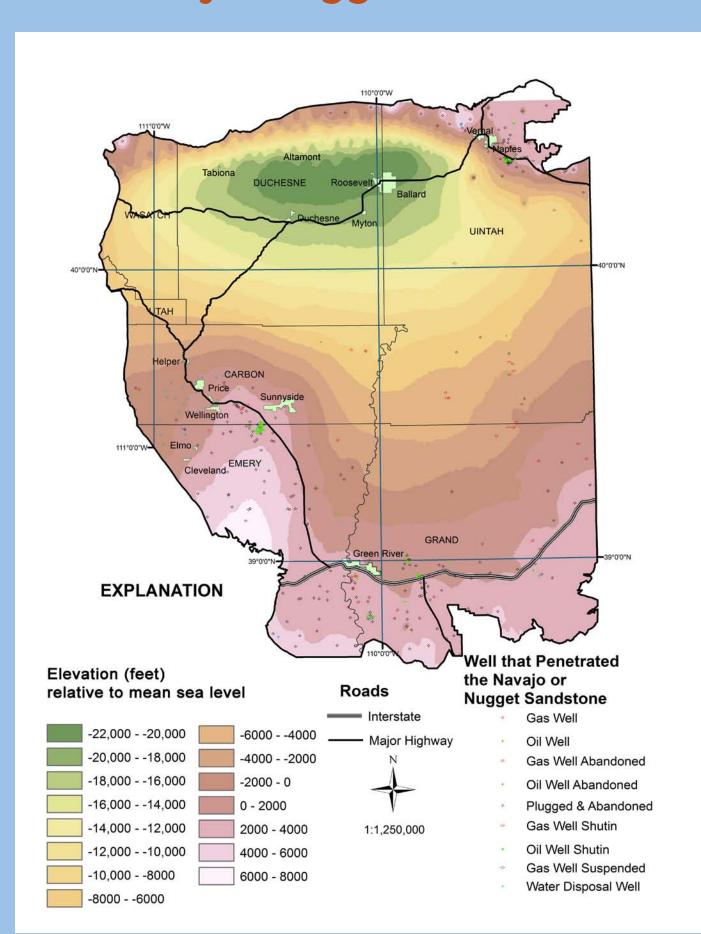
### Discussion

Water management/handling practices in the Uinta Basin, Utah cover a range of possibilities. Small operators are generally dependent on outside vendors to haul and dispose of produced water at commercial disposal wells or evaporation ponds. Large operators commonly design and construct complex water handling and disposal facilities that allow for capture and reuse of flow-back formation fracturing fluids, centralized facilities for treatment of produced water, and a series of injection wells or evaporation ponds for water disposal. Water treatments may include settling tanks which skim oil off the top and settle sediments at the base, oil-water separators, hydrocyclones, floatation cells, chemical flocculation of clays, and filtration systems (walnut shell or sock) before final disposal.

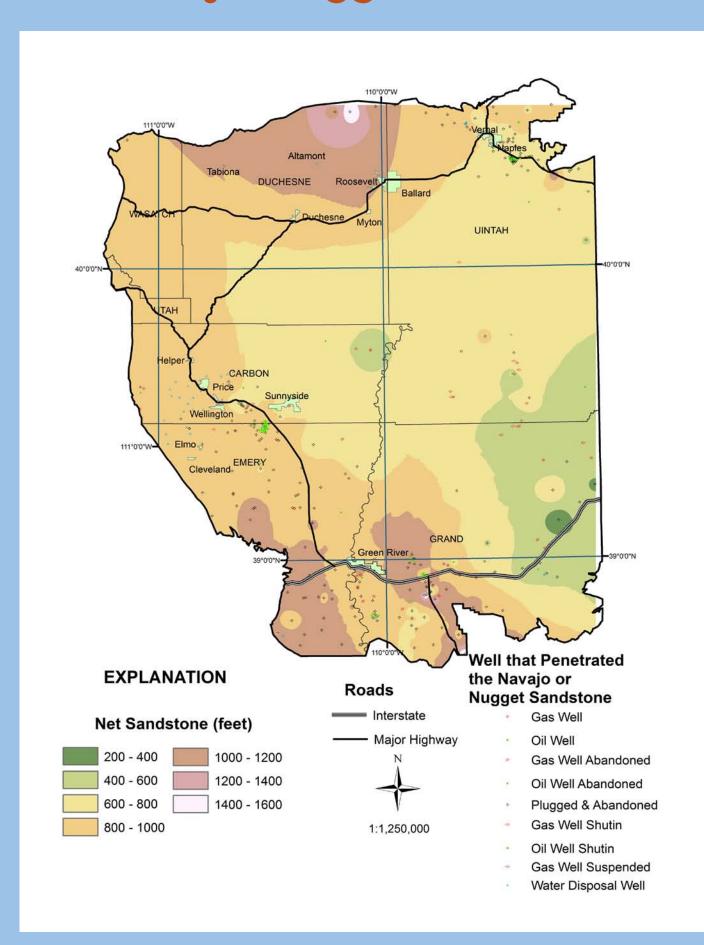
## Jurassic Navajo/ Nugget Sandstone



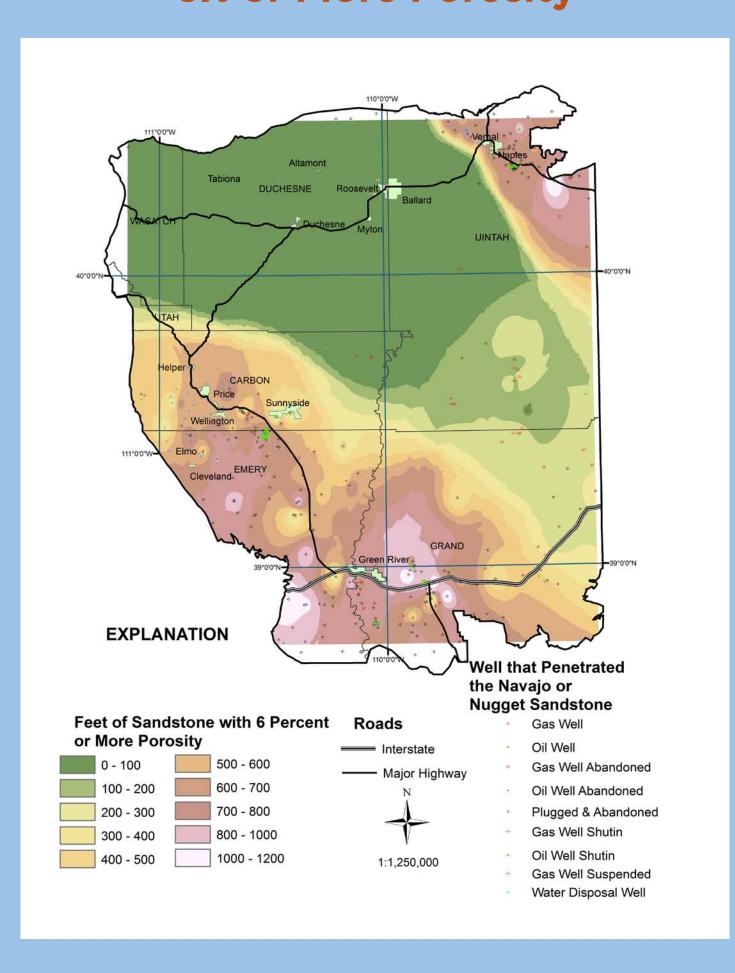
Structure on Top of the Navajo/Nugget Sandstone



**Net Sand Thickness (Feet) in the** Navajo/Nugget Sandstone



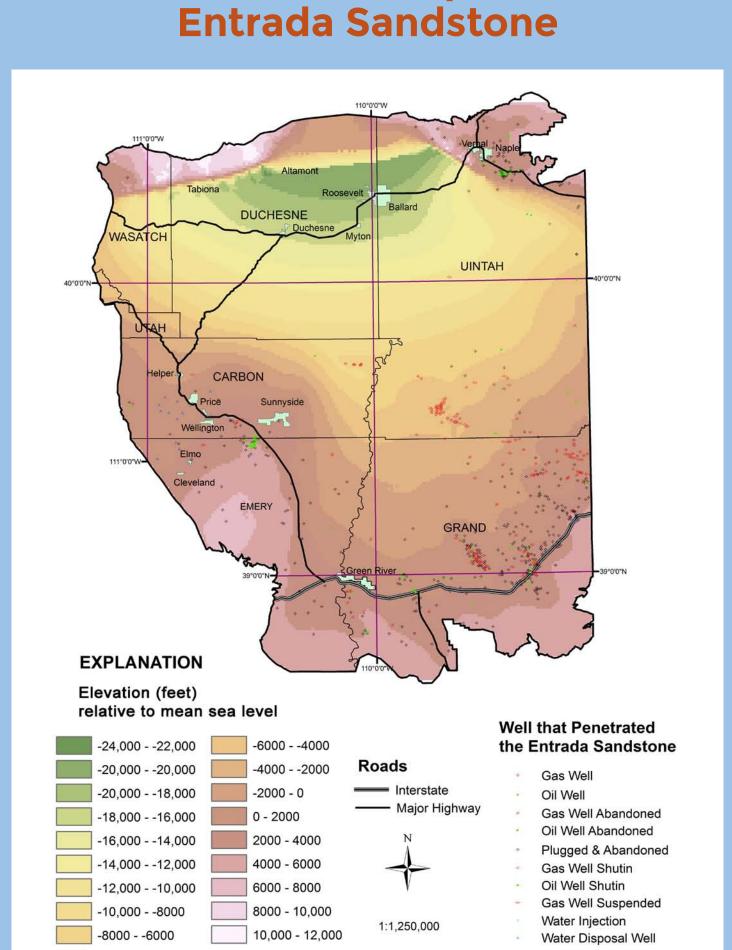
Feet of Navajo/Nugget Sandstone with 6% or More Porosity



### Jurassic Entrada Sandstone

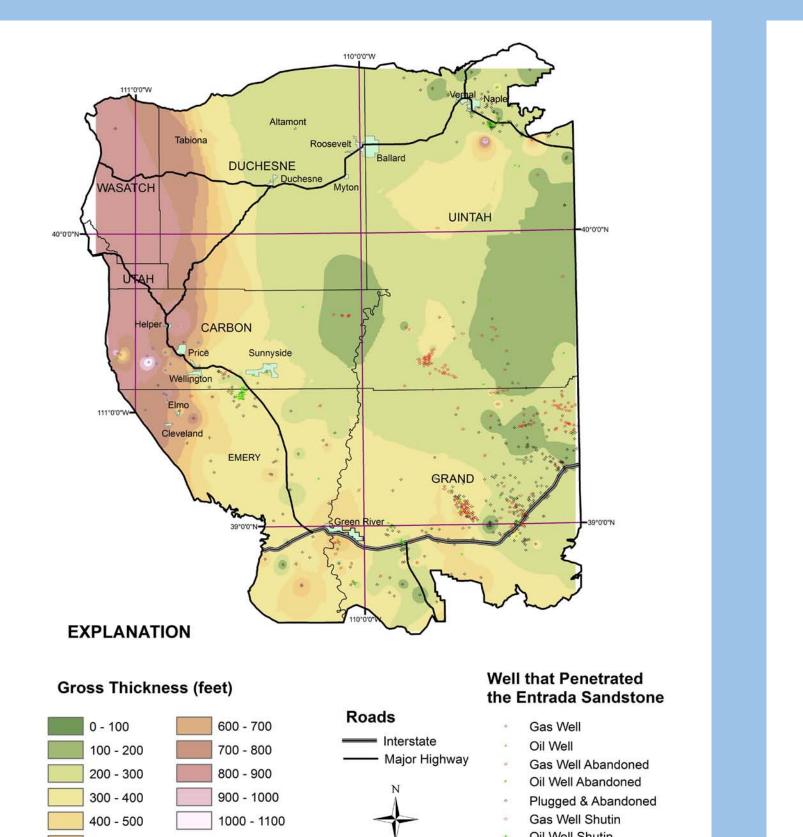


Structure on Top of the

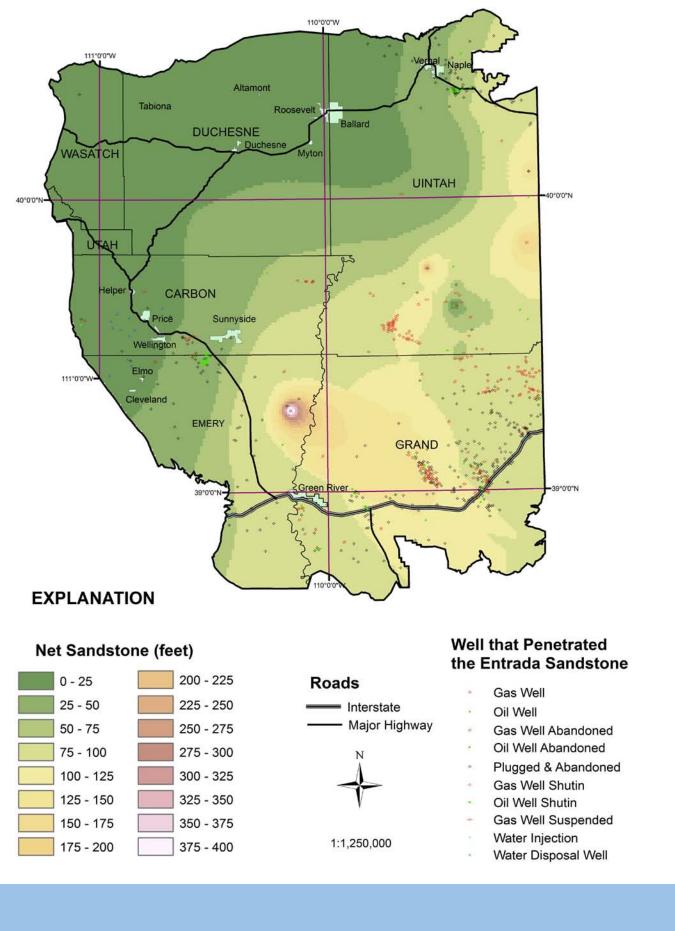


-12,000 - -10,000 6000 - 8000

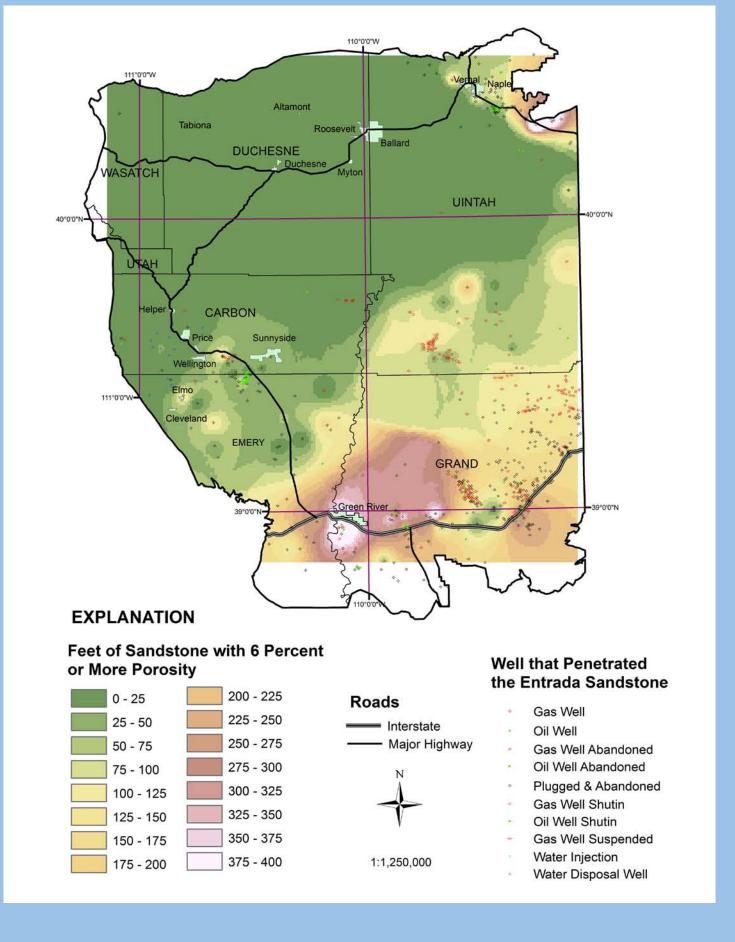
**Gross Sand Thickness (Feet)** 



**Net Sand Thickness (Feet)** 



Feet of Entrada Sandstone with 6% or More Porosity



# Aquifer and Reservoir Mapping

# Tight-Gas Sand and Shale-Gas Reservoirs

### Cretaceous Cedar Mountain Formation and Dakota Sandstone

Structure on Top of the Dakota Sandstone

**Cedar Mountain Formation** 

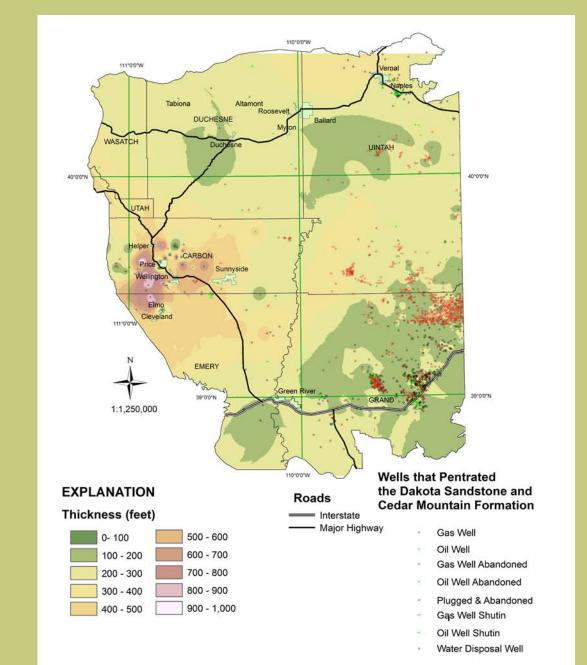
Elevation (feet) relative to mean sea level

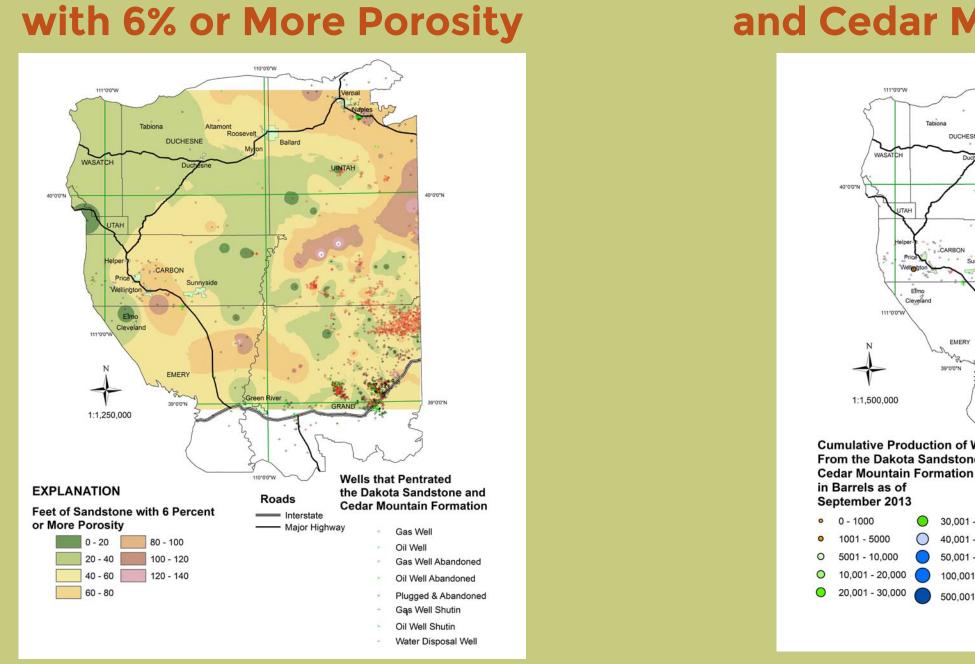
EXPLANATION

Feet of Sandstone with 6 Percent or More Porosity

0 - 20 80 - 100







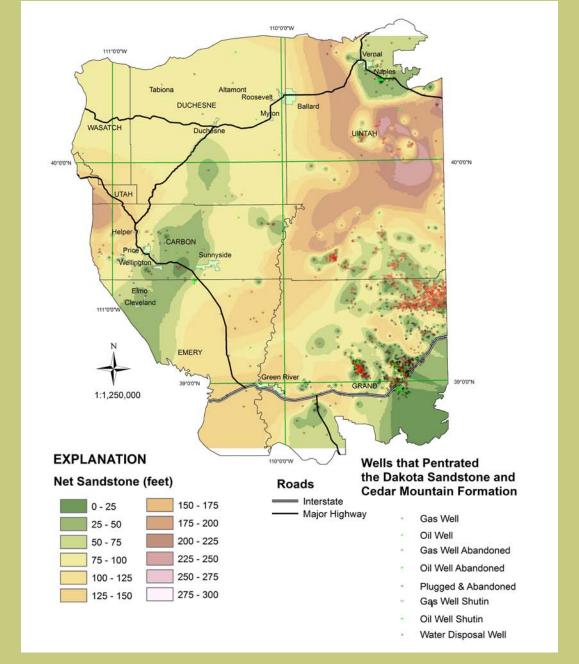
Cretaceous

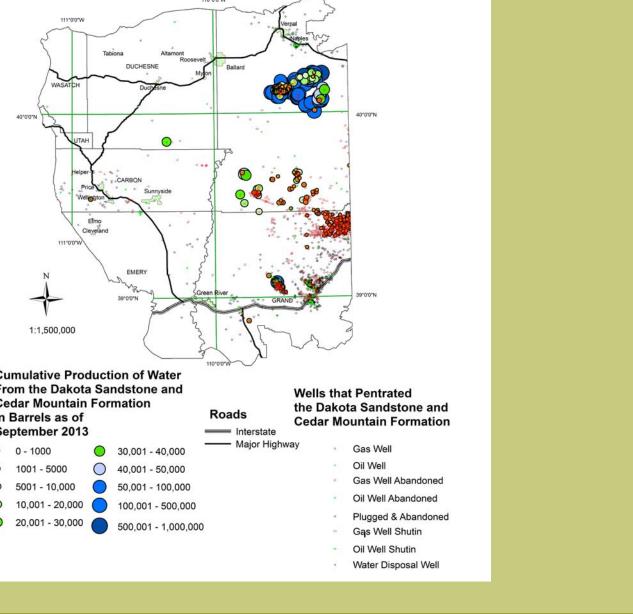
Mancos Shale

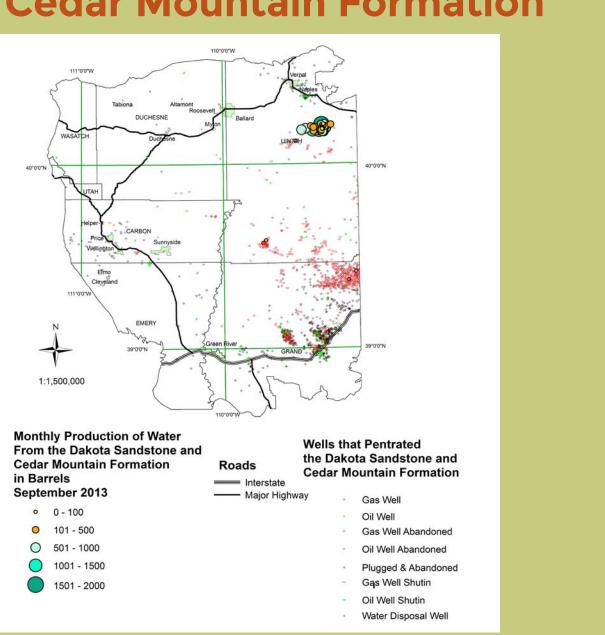
Marine Tununk Shale Member,

Mancos Shale, West Flank,

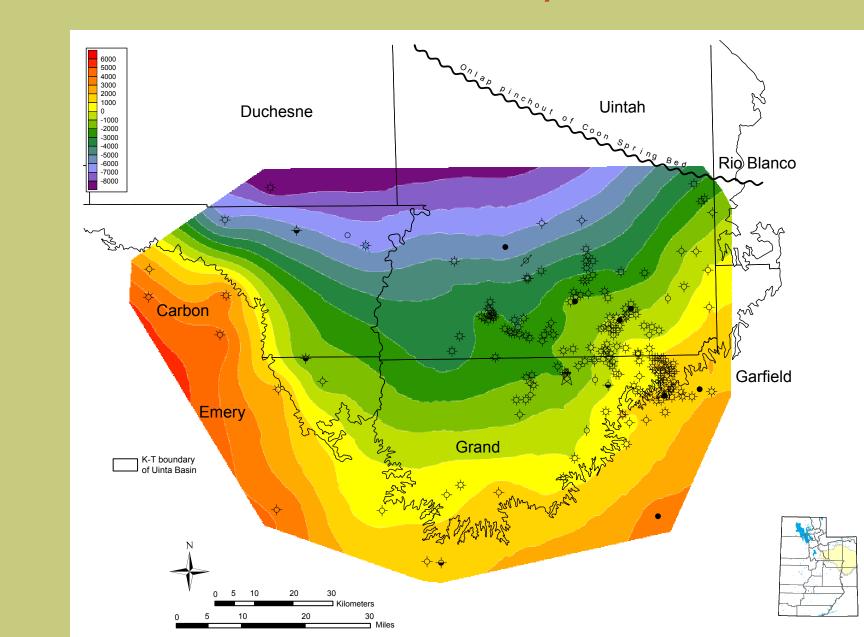
**Net Sand Thickness (Feet)** in the Dakota Sandstone and **Cedar Mountain Formation** 







### Structure on Top of Coon Springs Sandstone Bed, **Tununk Shale Member, Mancos Shale**

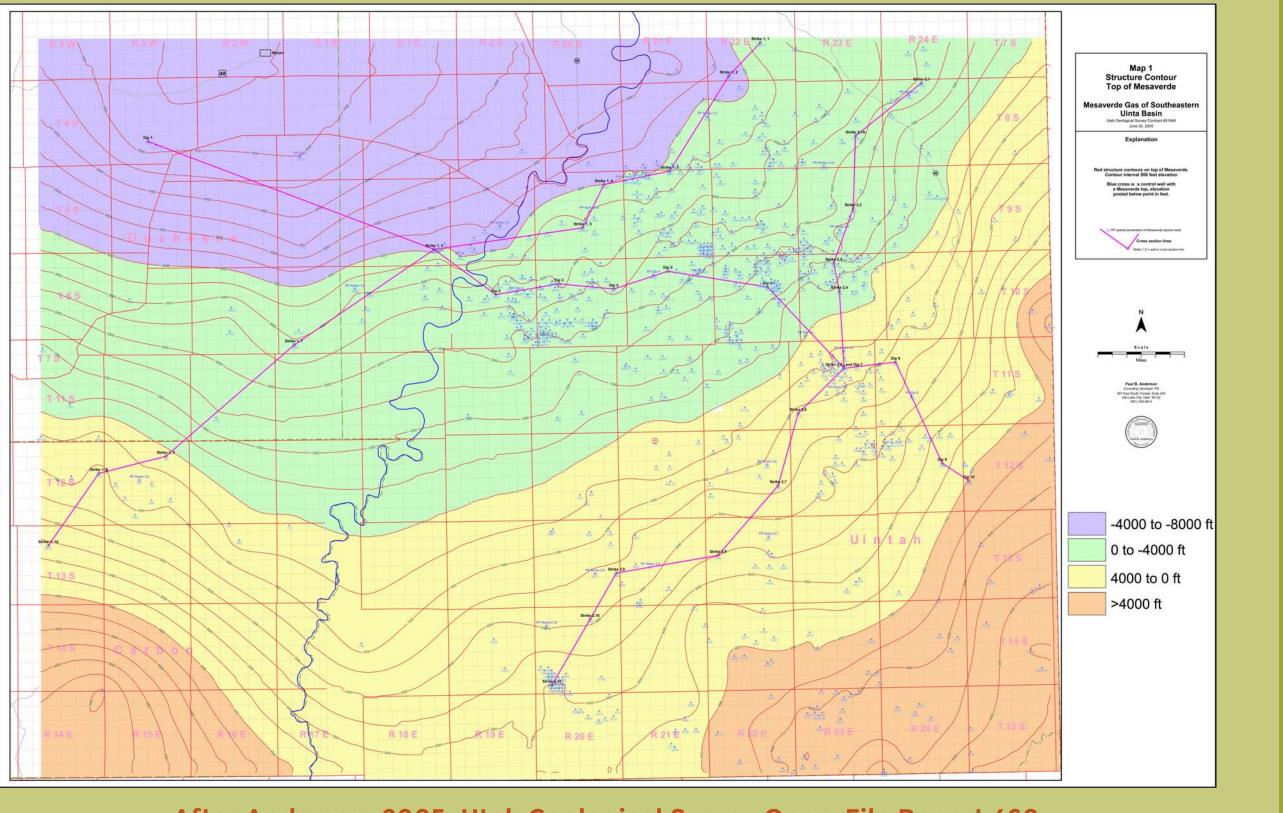


Deltaic to Coastal Plain Mesaverde Group, Book Cliffs, East-Central Utah

### Cretaceous Mesaverde Group

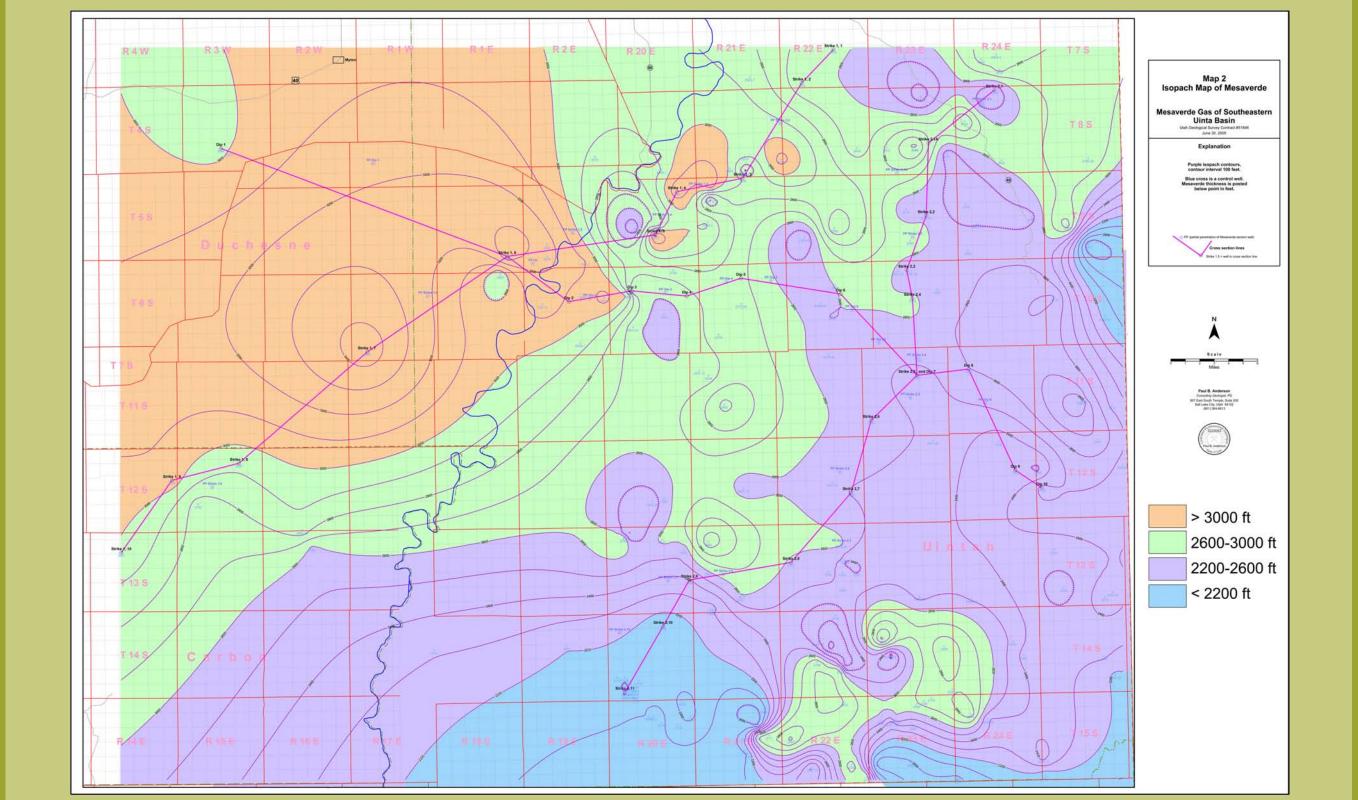


### Structure on Top of the Mesaverde Group



After Anderson, 2005, Utah Geological Survey Open-File Report 460

### **Gross Thickness (Feet) of Mesaverde Group**



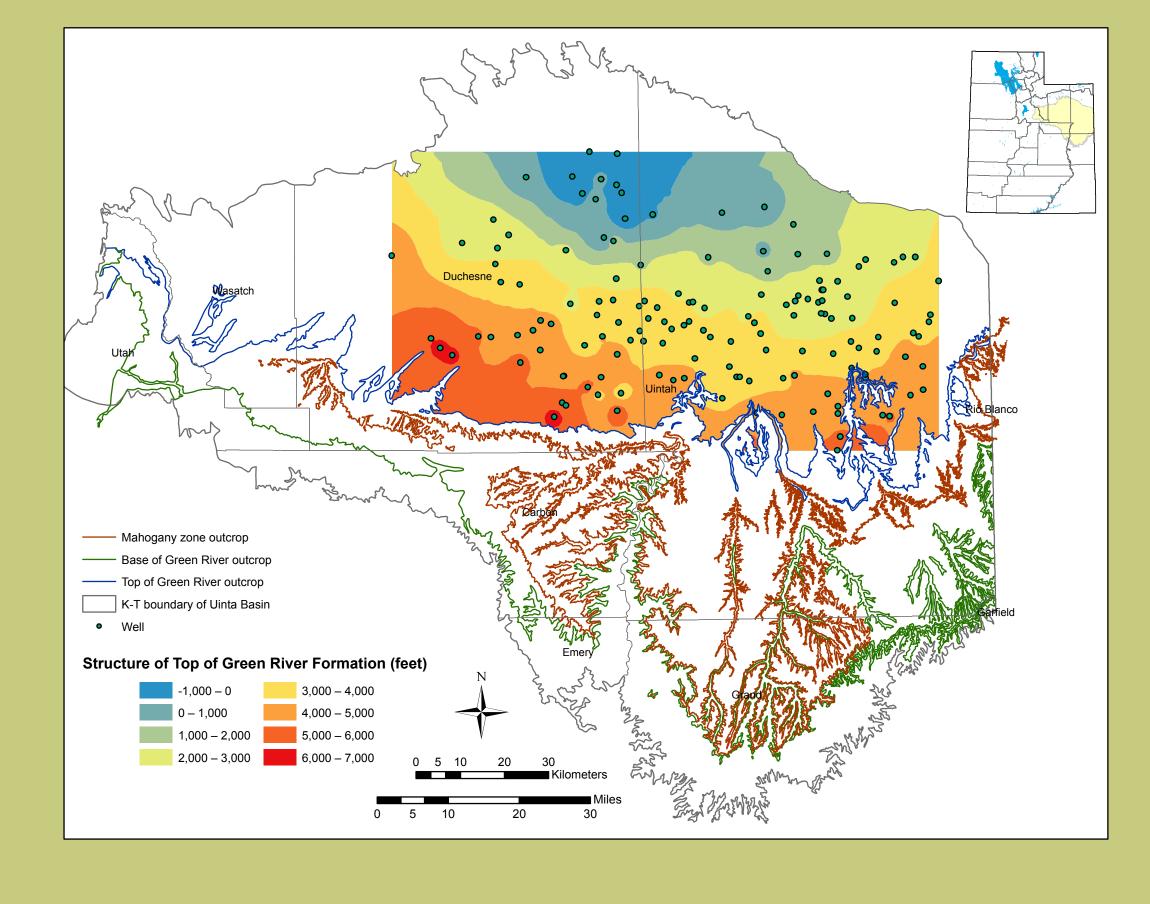
After Anderson, 2005, Utah Geological Survey Open-File Report 460

### Lacustrine Green River Formation, Nine Mile Canyon, Uinta Basin

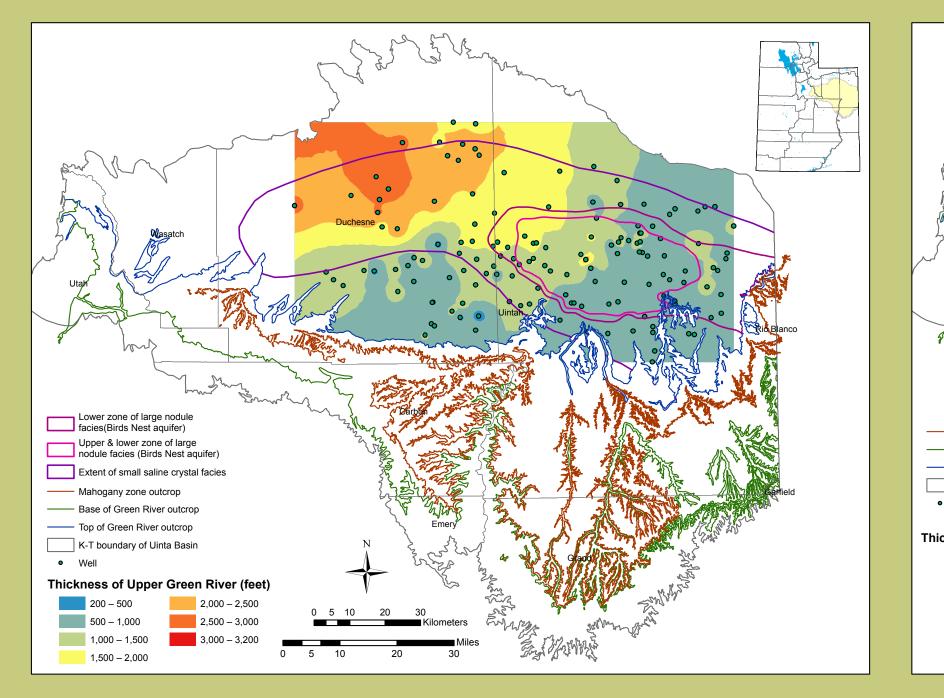
### Tertiary (Eocene) Green River Formation



### Structure on Top of the Green River Formation

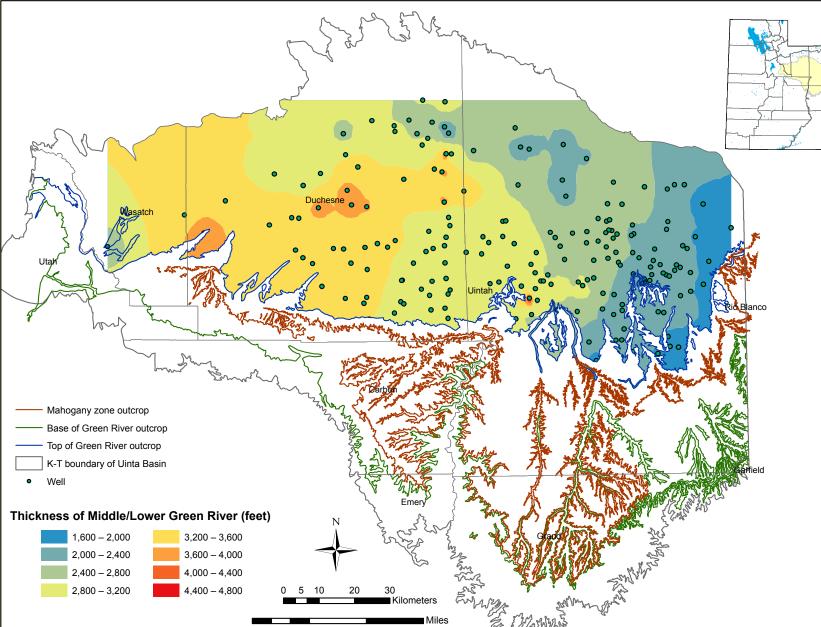


### Isopach Map of the Lower to **Middle Green River Formation**

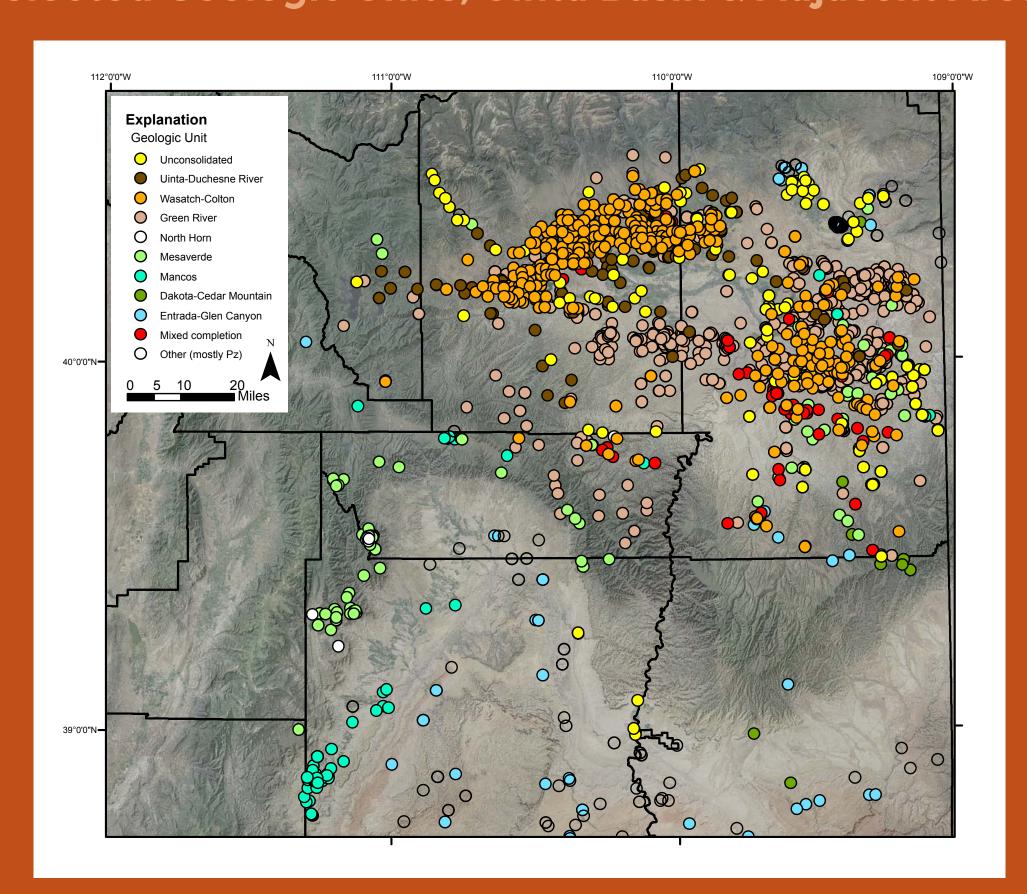


Formation's Birds Nest aquifer are also outlined.

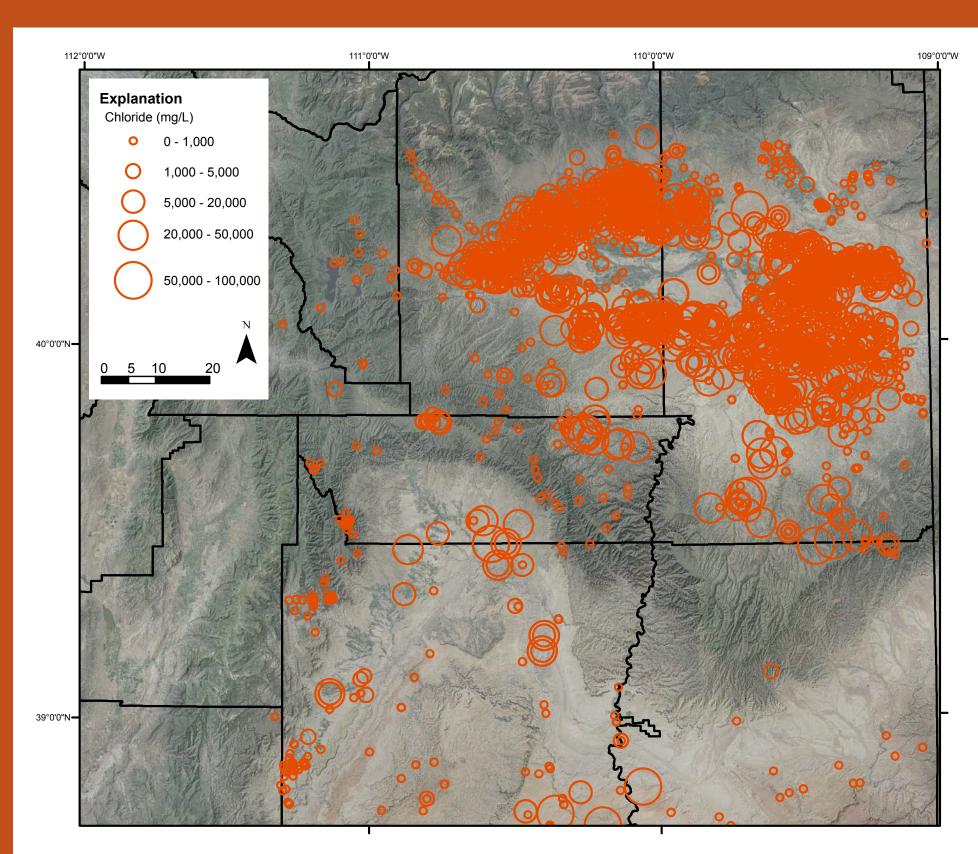
of the formation. Note the general thickening from south to north. The extent of large saline nodule facies and the small saline crystal facies of the upper Green River



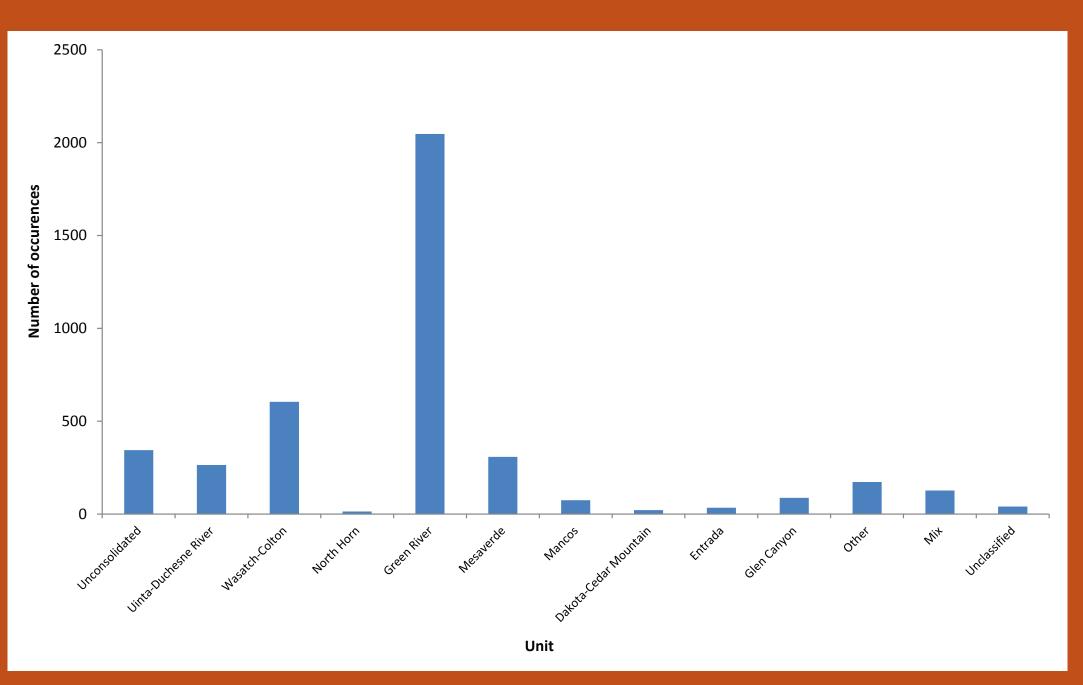
Thickness measured from the base of the formation to the Mahogany bed. Note the gradual thickening from east to west.



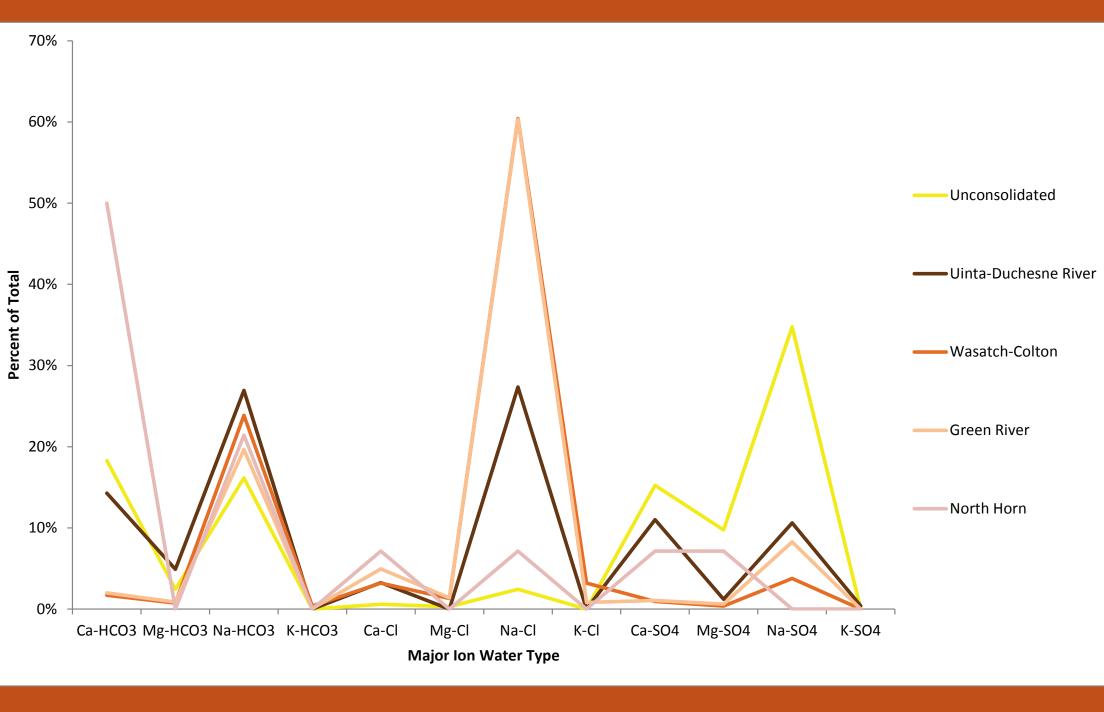
Map of Chloride Concentrations from Compiled Water Samples, Uinta Basin & Adjacent Areas



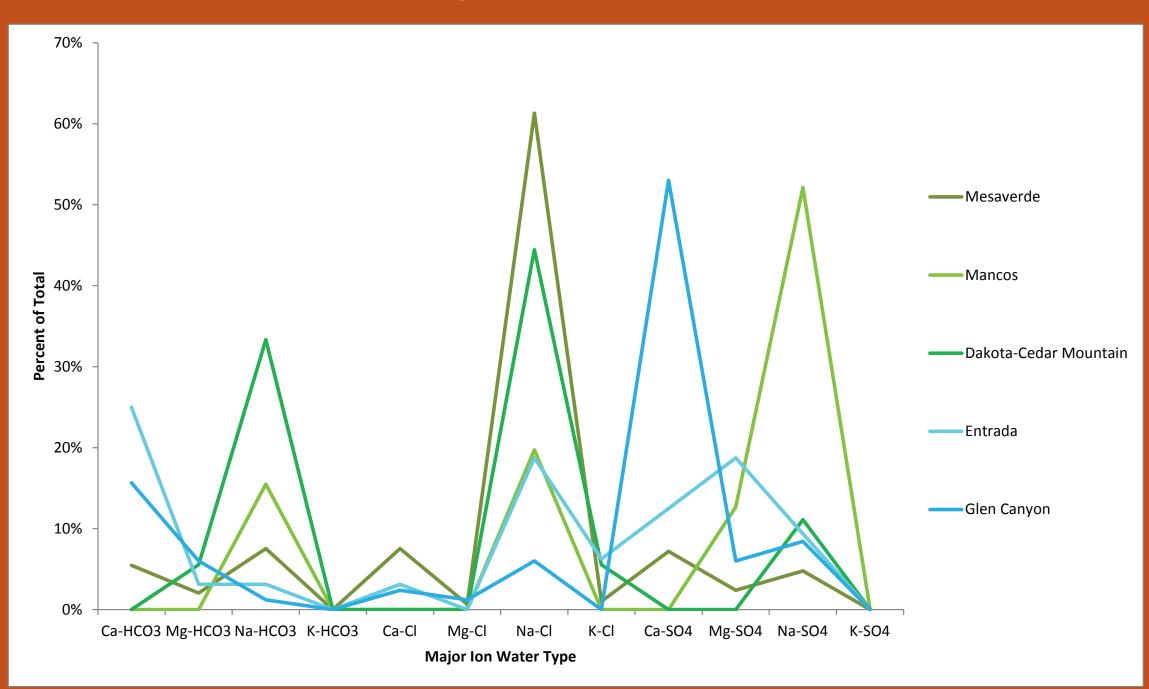
Summary of Compiled Water Chemistry by Geologic Unit



Summary of Major Ion Water Types for Younger Units

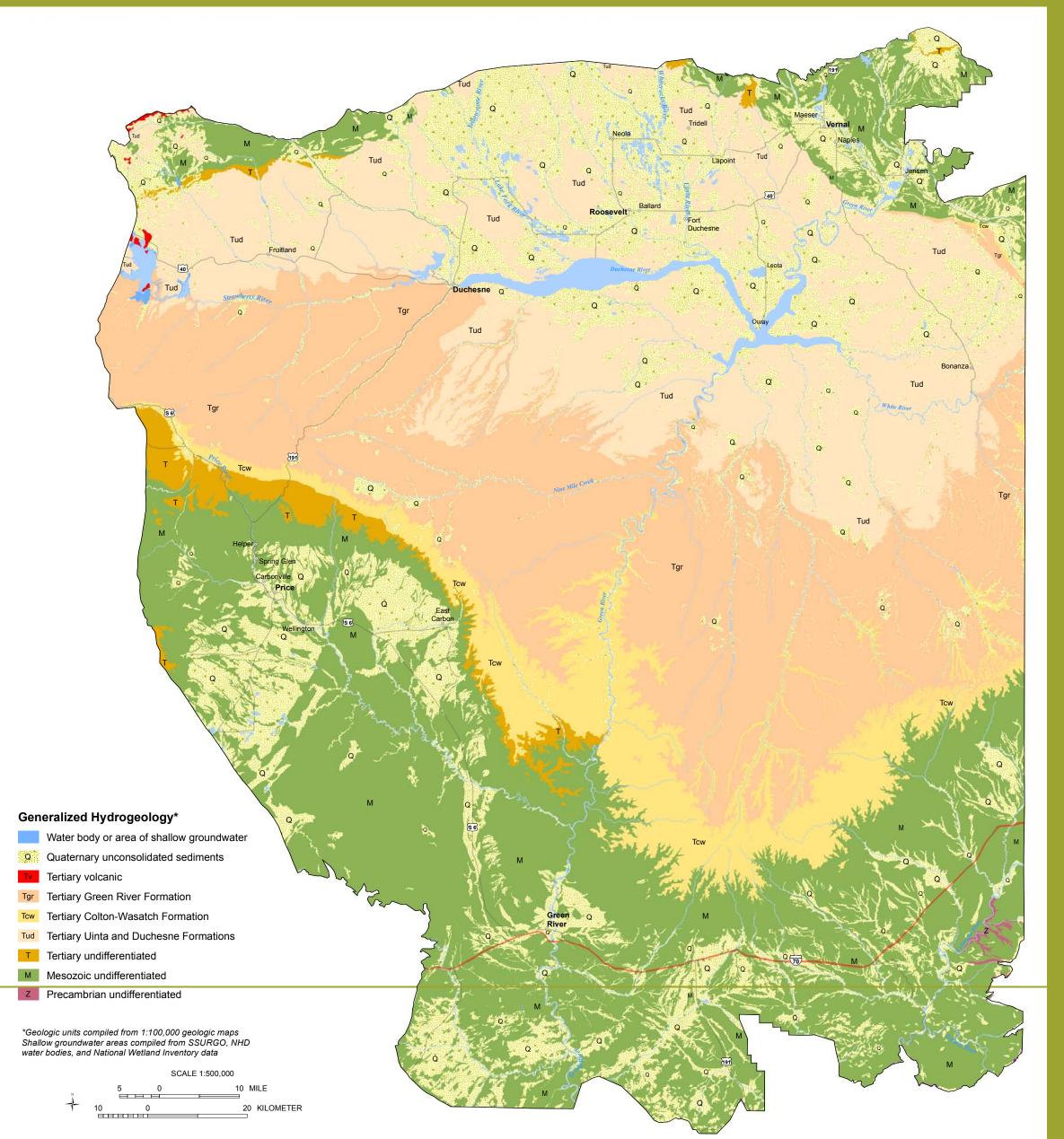


Summary of Major Ion Water Types for Older Units



# Water Quality from Alluvial Wells and Springs

General Hydrogeology of the Uinta Basin



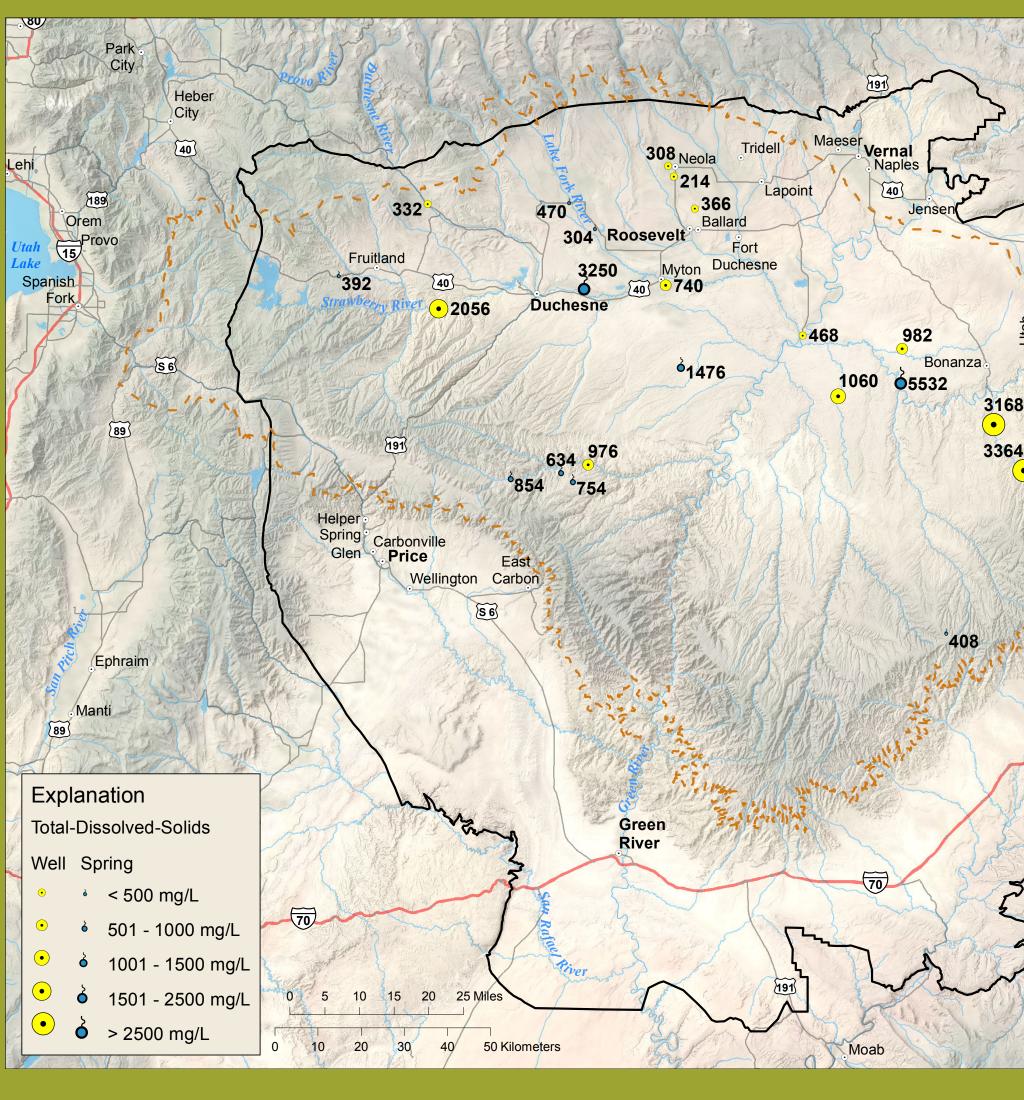
### Chemical Analysis for 22 Sites

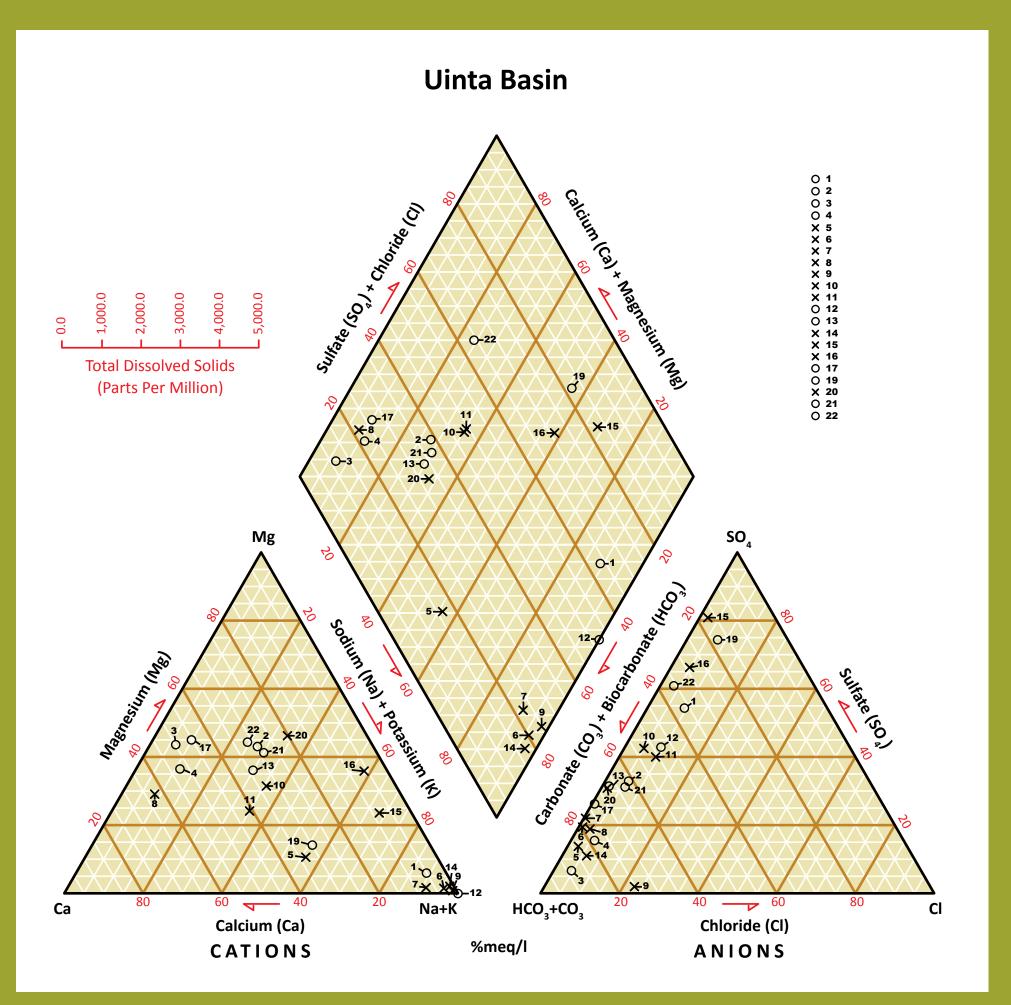
Field Parameters: pH, field temperature,

**General Chemistry:** total dissolved

<u>Dissolved Metals:</u> arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, silver, zinc

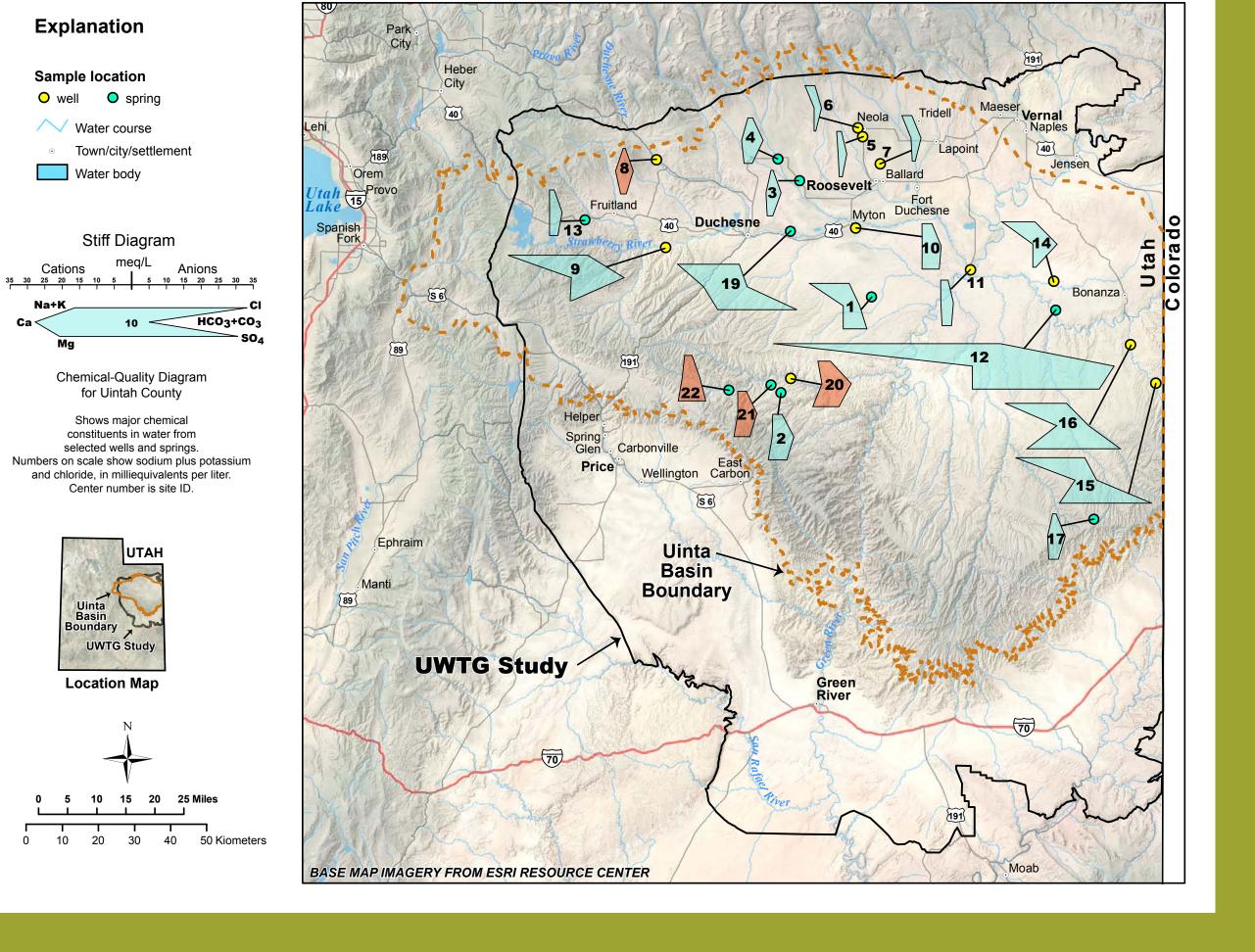
Volatile Organic Compounds (VOCs) and Total Petroleum Hydrocarbons: VOCs (BTEX MTBE) (benzene, omoethane, bromodichloromethane, bromoform, chloromethane, chloroform, chlorodibromomethane, vinyl chloride, total xylene, toluene)





Water chemistry for 21 sites sampled during spring and summer 2013 in the Uinta Basin. X's correspond to alluvial well samples, circles correspond to spring samples

### Piper Diagram of General Solute Chemistry Stiff Diagrams for Water Sampling Sites in the Uinta Basin



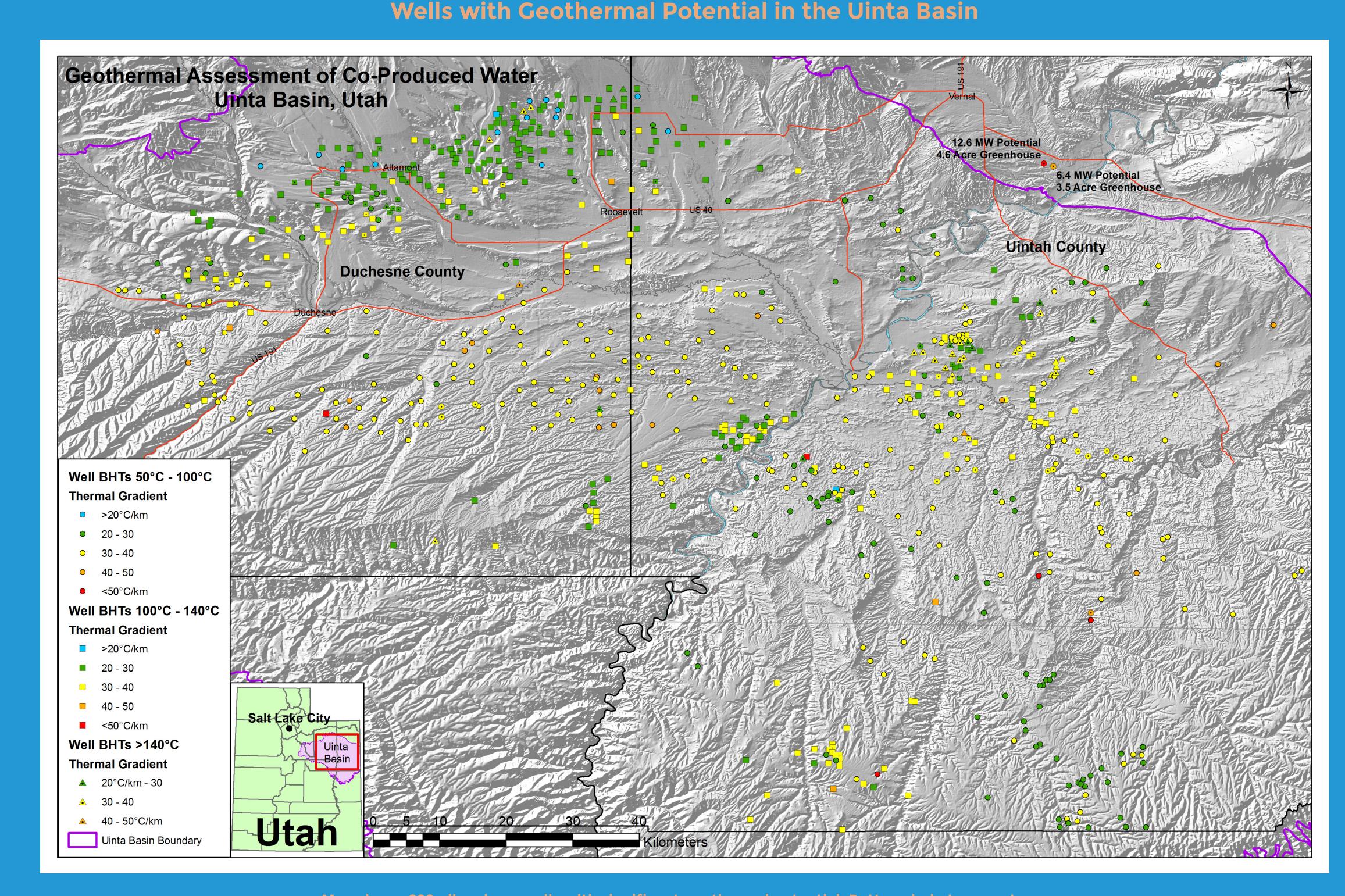
The sites are identified by their location number. Stiff diagrams illustrate solute chemistry. All data are from 2013. Blue polygons indicate the site was sampled for and had detectable VOCs; orange indicates no VOCs were detected (sites 8, 20, 21, and 22). Diagrams having similar shapes and sizes reflect similar chemistry types; the variability of diagrams reflects different and mixed aquifer sources.

### Results

- TDS ranges from 214 to 5532 mg/L; variable water quality; aquifers and springs are not interconnected
- Nitrate-no sites exceeded 10 mg/L; most <0.1 mg/L
- No dissolved metals exceeded water-quality standards: some with fracking fluids from previous investigations had detectable concentrations:
- o 7 sites for barium
- o 7 sites for chromium
- o 14 sites for zinc
- o 20 sites had above DL for Cu
- Overall low TDS with 77% of sites <2000 mg/L, especially from springs near the recharge area in the Uinta
- 18 of 22 sites had detectable VOCs, some had 2 or more

# Geothermal Potential

PANELIII



- Bottom-hole temperatures and co-produced water data for 730 oil and gas wells distributed across the entire basin were combined with existing lithological information.
- Calculations reveal an average geothermal gradient of about 27.0°C/km implying that wells producing fluids from depths > 2 km (6562 ft) will likely have temperatures of > 54°C (129°F). The average heat-flow value of wells with corrected BHTs is 67.1 mW/m2. These results are generally typical for gradient and heat-flow values in the Colorado Plateau.
- Thermal outputs are calculated using well production rates and fluid temperatures. The average thermal output is 110 kW per well and maximum output is as high as 12 MW-energy currently lost to waste water.
- Co-produced water temperatures in 673 wells are above 50°C (122°F) and may be suitable for direct-use applications such as greenhouses, space heating, and aquaculture.
- Binary geothermal power plants generally require a minimum temperature of 140°C (248°F) to achieve acceptable efficiency and 26 wells across the basin meet or exceed such temperatures.
- The high volume of co-produced water at wells with > 50°C (122°F) temperatures along with the benefit of existing infrastructure make the Uinta Basin a candidate for the development of direct-use geothermal applications with the potential to support binary geothermal power production.

### References

intze, L.F., and Kowallis, B.J., 2009, Geologic history of Utah: Brigham Young University Geology Studies Special Publication 9, 225 p.